# Length Variations of European Baselines Derived from VLBI and GPS Observations*

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**Abstract**

Results of VLBI and GPS observations were analyzed with goal to investigate differences in observed baseline length derived from both techniques. VLBI coordinates for European stations were obtained from processing of all available observations collected on European and global VLBI network. Advanced model for antenna thermal deformation was applied to account for change of horizontal component of baseline length. GPS data were obtained from re-processing of the weekly EPN (European Permanent GPS Network) solutions. Systematic differences between results obtained with two techniques including linear drift and seasonal effects are determined.

## 1 Introduction

European region is one of the most intensively studied areas of the Earth from the point of view of regional geodynamics. There are more than 100 permanently operating GPS receivers, about 10 permanent VLBI stations and more than 10 permanent SLR stations. Lately much attention has been devoted to comparison and combination of results obtained using different space geodesy techniques. This work is devoted to comparison of baseline length variations derived from GPS and VLBI observations, continuing the cycle of works on this problem, see e.g. [1–5, 7, 11, 13]. It should be mentioned here that observed changes of the baseline length on the one hand are resulted by insufficient corrections for observational effects such as thermal deformations of VLBI antennas, for example, or errors in modeling of tropospheric refraction, but on the other hand they are subjected to a number of insufficiently studied or not taken into account properly geophysical effects that can result in the real changes of the baseline length, these effects may be atmospheric and snow loading, tides, postglacial rebound, and so on. It is important that the majority of these effects has both seasonal and secular components.

In this study we have analyzed VLBI and GPS observations at 6 European stations carrying out both VLBI and GPS regular observations and having long enough observational history.

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# 2 Data used

## 2.1 VLBI observations

VLBI baseline lengths were computed with the OCCAM package using all available 24h sessions for the period of 1983.9–2001.5. Details of the method used can be found in [9].

Linear trend in the baseline lengths was computed for the whole period of observations and, for more accurate comparison with GPS data, for the period of 1996.0-2001.0. Only later results are presented in this study. In [5] we compared linear trend in variations of baseline length derived from the observations over the period 1996.0–2001.0 with ones computed using all available VLBI sessions over a period 1990.0–2001.4. Differences of estimated rates are inside one sigma interval for all baselines analyzed here.

For more strict account for variation in baseline lengths due to thermal antenna deformations we used advanced model of this effect [10] which allow to correct observed station position not only for vertical but also for horizontal displacement. At this stage of the research we used zero time delay between change of air and telescope construction temperature, because of lack of such a data for most of antennas. However, this mismodelling will effect only intra-day displacement of the telesope reference point, but not seasonal variations.

It should be mentioned here that account for horizontal displacement is especially important for processing regional networks, whereas vertical displacement due to thermal deformations prevails in variations of global baselines length. In particular, errors in modelling of this effect may be a possible reason of seasonal baseline length variations found e.g. in [12].

Variation of baseline lengths obtained from VLBI data are shown in Figure 1. Unfortunately, stations Crimea and Yebes are not equipped with GPS receiver.

## 2.2 GPS observations

For computation of baseline lengths between European GPS stations we used weekly EPN solutions distributed in SINEX files. However, this solutions are not suitable for immediate use in geodynamical analysis because they cannot provide homogeneous long-time coordinate time series due to periodic changes in reference coordinate system and set of fiducial stations. For this reason, direct use of the EUREF solutions shows jumps in baseline length variations [4]. Besides, method of computation of station coordinates used in EPN is based on using tight constrains to fiducial stations which cause a distortion of the network, i.e. fictive variations in baseline lengths (see e.g. [6]).

So, variations of baseline lengths from GPS data were obtained from analysis of coordinate time series for EPN stations computed by the method described in [8]. This computation is based on de-constraining of the official EPN solutions with further transformation to ITRF2000. For this study we used 6-parameter Helmert transformation to avoid loss of seasonal geophysical signal in baseline length. Using our independent coordinate time series allows us to obtain realistic station displacement practically free of network distortion for all EPN stations over the period 1996.0–2001.0.

Variation of baseline lengths obtained from GPS data are shown in Figure 2. Unfortunately, MADR coordinate time series is too short (less than two years) that does not allow to get reliable results. It should be mentioned that errors in GPS baseline length significantly

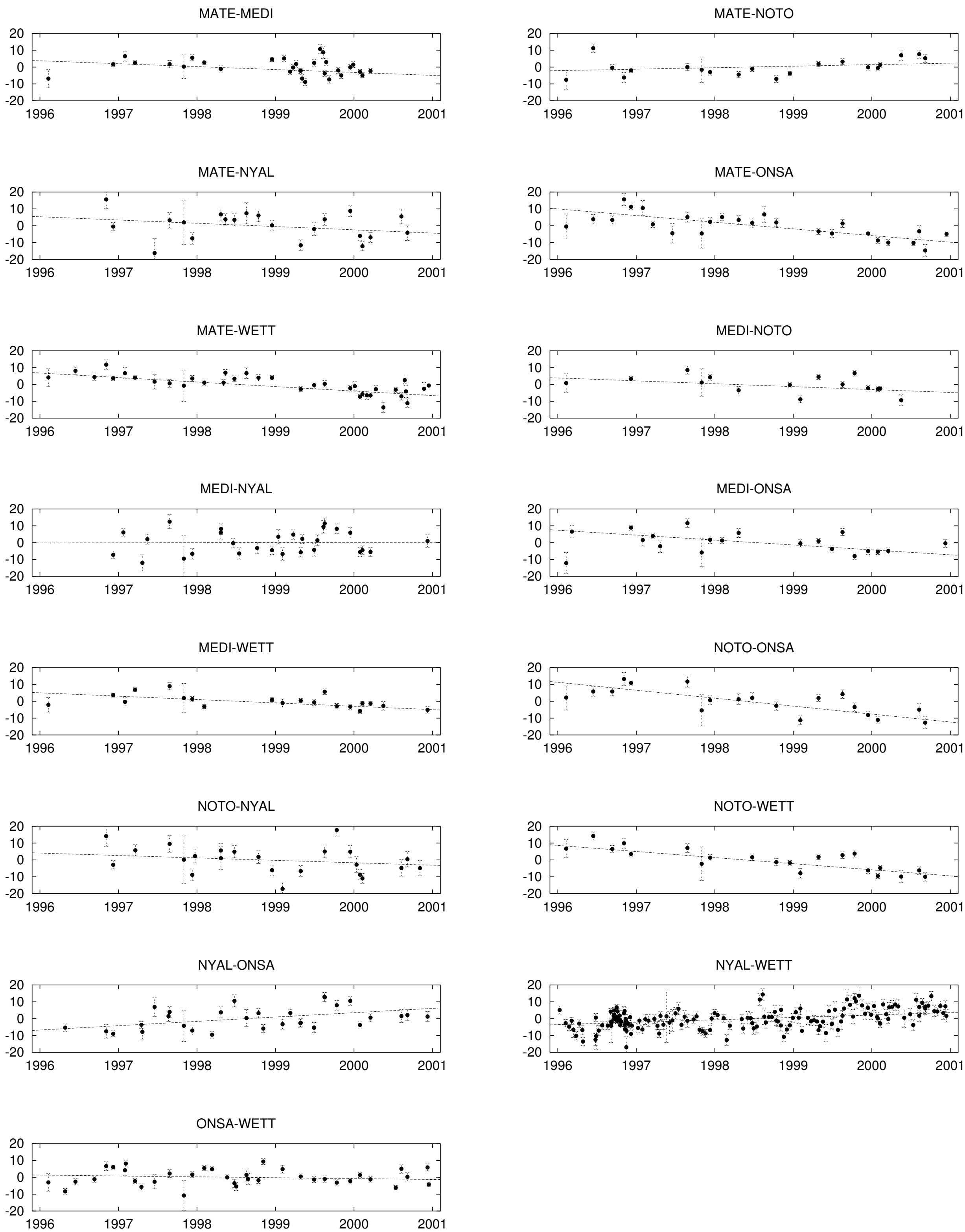


Figure 1: Variation of VLBI baseline lengths, mm.

decrease during a period under investigation. E.g., one can see abnormal trend in MATE displacement in 1996. However, that does not influence result very much due to relatively small weight of these data.

### 2.3 Atmospheric loading

One of the most important factor affecting variations of station coordinates derived from space geodesy observations is atmospheric loading. We investigated influence of this effect using 3-dimensional atmospheric loading time series provided by H.-G. Scherneck [14]. The data were averaged over a week interval corresponding to every GPS week and variations of baseline lengths were computed from these weekly values. Variation of baseline lengths obtained from analysis of atmospheric data are shown in Figure 3.

It is interesting that baseline length variations contain not only seasonal but also secular component, even for short baselines, especially for continental-coastal ones, in particular baselines including Wettzell stations which are often used in studies on European geodynamics, e.g. [2–4, 13]. The reason of that may be long-periodic or progressive weather and climate changes, but period of our investigation is too short to separate them.

Since variations in height component of station displacement due to atmospheric loading prevail, this effect is especially significant for global baselines. For regional networks horizontal displacements yield main contribution to variation of baseline lengths.

## 3 Results and conclusions

Results of computation of variations in baseline lengths are presented in 1. One can see that values of rates obtained from VLBI and GPS observations are in good agreement for most baselines. Unfortunately, it is not the case for seasonal variations. Obviously, interval of investigation is too short and number of used VLBI observations is too small for many baselines.

Indeed, it would be important to verify our results using data obtained from other space geodesy techniques, but only MATE and WETT stations are equipped with SLR units, and only NYAL station is equipped with DORIS beacon (which is explained by difficulties in collocation of DORIS beacon and VLBI antenna due to radio frequency interference).

It is also remarkable that influence of atmospheric loading on baseline length rate is significant for many baselines. Evidently, this effect must be investigated more carefully and properly accounted during geodynamical analysis.

Figure 4 shows dependence of error in baseline length rate on length of baseline. It is interesting that for GPS data error is practically the same for all baselines unlike VLBI data.

Further steps of our work will include new re-computation of EPN coordinate time series based on new combination of individual EPN Analysis Center solutions, reprocessing of VLBI data with new version of software, and more complete analysis of various factors effected variations of baseline lengths. Analysis of variations in vertical component of station displacement is also planned.

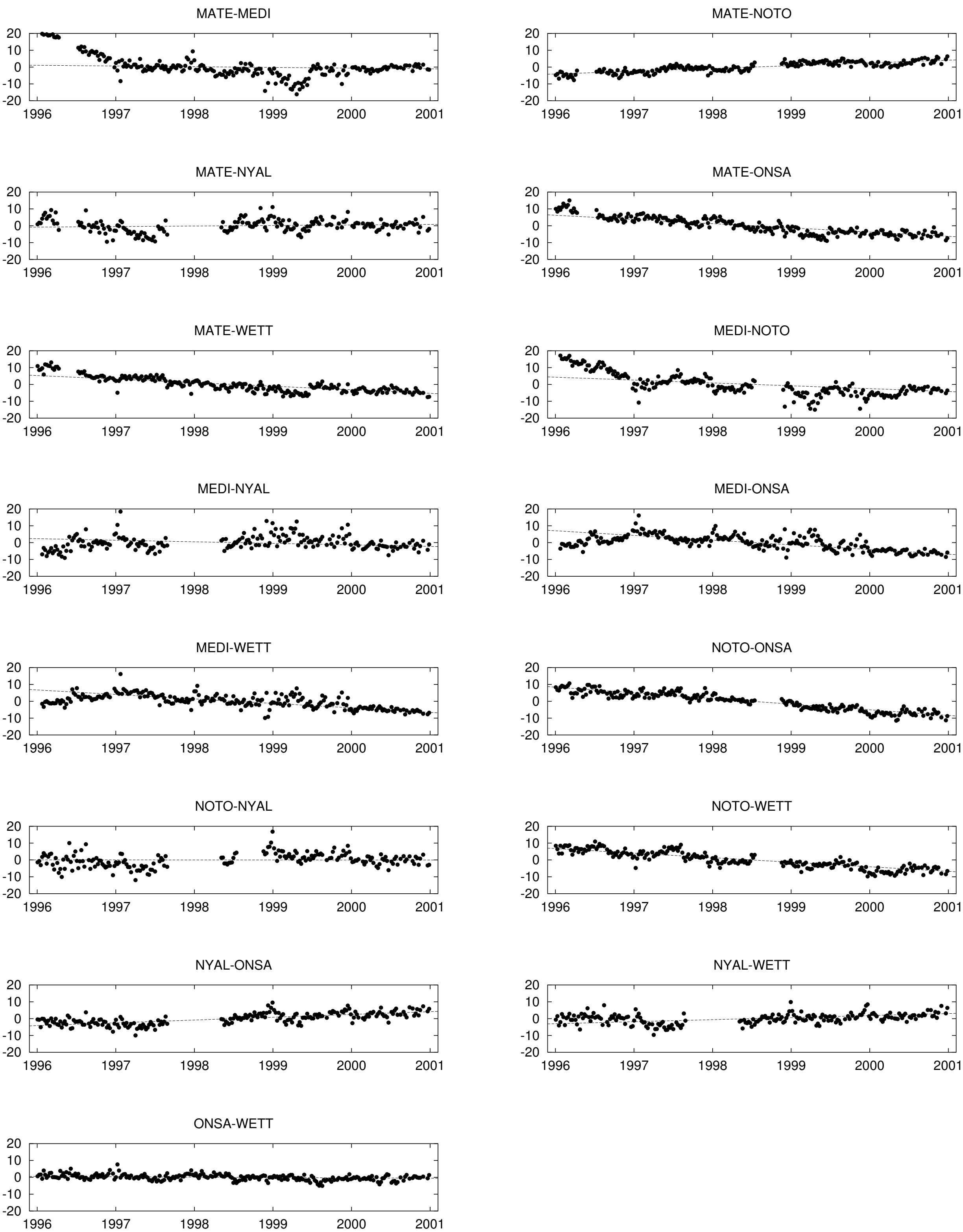


Figure 2: Variation of GPS baseline lengths, mm.

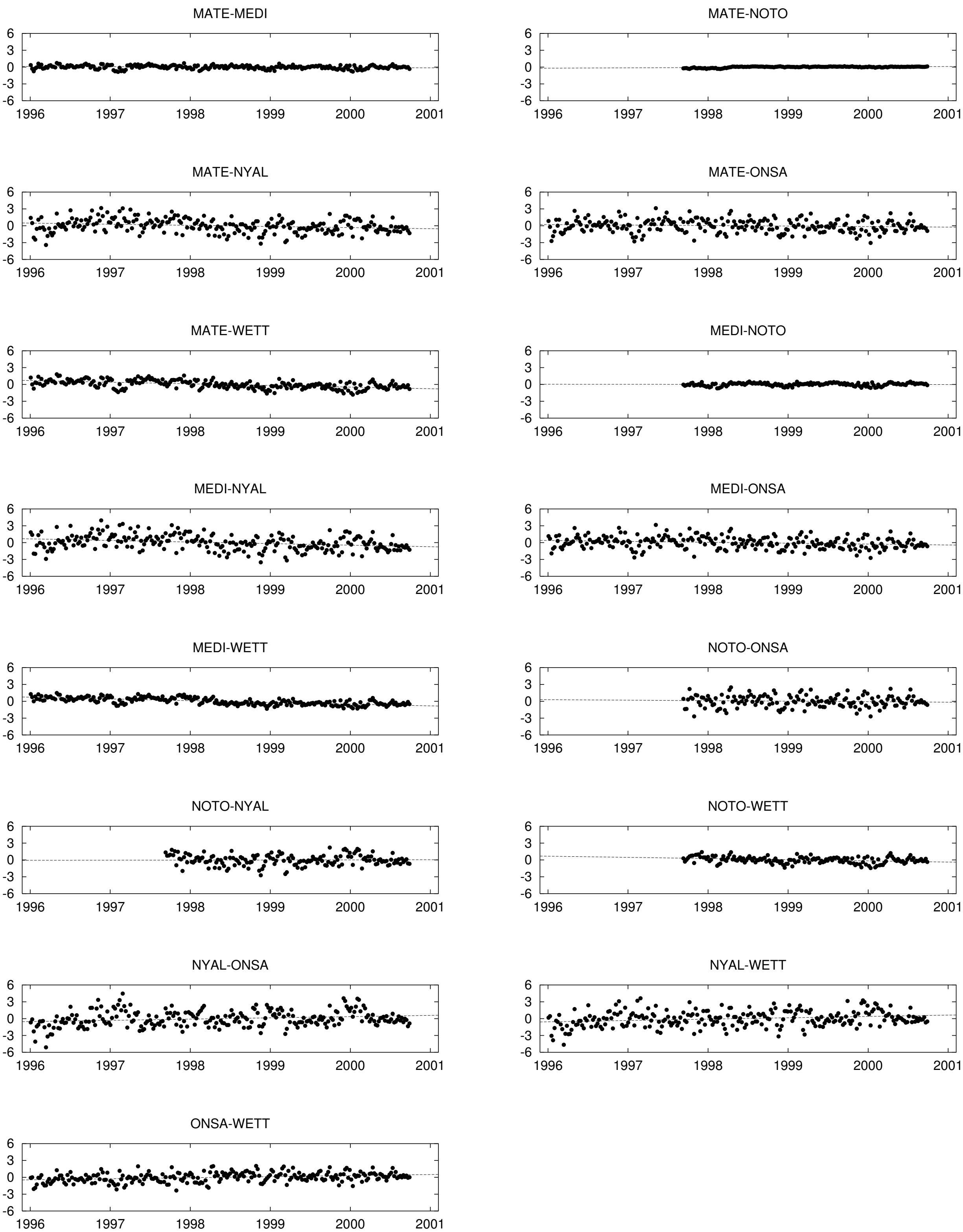


Figure 3: Variation of baseline lengths due to atmospheric loading, mm.

Table 1: Results of analysis of variation of baseline lengths: baseline length (L), km, number of epochs (N) processed and found in the IVS data base, linear trend (Rate), mm, amplitude of annual term (As), mm, amplitude of semiannual term (Asa), mm.

| Base | L | VLBI | | | | GPS | | | | Atmospheric loading | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | Rate | Aa | Asa | N | Rate | Aa | Asa | Rate | Aa | Asa |
| MATE | 597 | 31 | –1.78 | 0.37 | 2.23 | 224 | –0.97 | 3.42 | 1.26 | –0.05 | 0.16 | 0.05 |
| MEDI | | 35 | ±0.63 | ±0.99 | ±1.12 | | ±0.21 | ±0.43 | ±0.36 | ±0.01 | ±0.03 | ±0.03 |
| MATE | 444 | 20 | +0.62 | 3.21 | 2.17 | 212 | +1.57 | 0.51 | 0.35 | +0.06 | 0.06 | 0.02 |
| NOTO | | 23 | ±0.71 | ±1.16 | ±1.29 | | ±0.10 | ±0.19 | ±0.16 | ±0.01 | ±0.01 | ±0.01 |
| MATE | 4190 | 21 | +0.27 | 6.57 | 3.35 | 192 | +0.16 | 0.70 | 0.53 | –0.20 | 0.27 | 0.15 |
| NYAL | | 24 | ±1.74 | ±2.28 | ±2.49 | | ±0.21 | ±0.37 | ±0.30 | ±0.05 | ±0.11 | ±0.11 |
| MATE | 1886 | 26 | –3.86 | 2.64 | 1.19 | 229 | –2.69 | 0.89 | 0.74 | –0.09 | 0.32 | 0.17 |
| ONSA | | 29 | ±0.51 | ±1.13 | ±1.04 | | ±0.13 | ±0.25 | ±0.20 | ±0.05 | ±0.10 | ±0.10 |
| MATE | 990 | 36 | –2.51 | 1.83 | 1.46 | 229 | –2.25 | 1.47 | 0.46 | –0.29 | 0.25 | 0.10 |
| WETT | | 42 | ±0.40 | ±0.82 | ±0.71 | | ±0.10 | ±0.19 | ±0.17 | ±0.03 | ±0.05 | ±0.05 |
| MEDI | 893 | 15 | –1.22 | 3.39 | 4.14 | 221 | –2.37 | 3.90 | 1.33 | –0.01 | 0.23 | 0.03 |
| NOTO | | 19 | ±0.94 | ±1.62 | ±2.40 | | ±0.17 | ±0.33 | ±0.28 | ±0.02 | ±0.03 | ±0.02 |
| MEDI | 3776 | 28 | –0.55 | 3.13 | 3.31 | 201 | –0.73 | 1.61 | 1.15 | –0.28 | 0.41 | 0.08 |
| NYAL | | 34 | ±1.13 | ±1.87 | ±1.92 | | ±0.23 | ±0.38 | ±0.34 | ±0.06 | ±0.11 | ±0.11 |
| MEDI | 1429 | 20 | –3.13 | 2.76 | 1.15 | 238 | –2.48 | 1.87 | 1.43 | –0.16 | 0.17 | 0.19 |
| ONSA | | 25 | ±0.76 | ±1.75 | ±1.68 | | ±0.13 | ±0.26 | ±0.22 | ±0.05 | ±0.09 | ±0.09 |
| MEDI | 522 | 20 | –2.14 | 2.56 | 1.25 | 238 | –2.41 | 1.55 | 0.88 | –0.31 | 0.06 | 0.10 |
| WETT | | 22 | ±0.49 | ±1.15 | ±1.11 | | ±0.13 | ±0.26 | ±0.22 | ±0.02 | ±0.04 | ±0.04 |
| NOTO | 4580 | 23 | –1.62 | 6.02 | 3.73 | 189 | –0.05 | 0.39 | 0.44 | +0.02 | 0.36 | 0.24 |
| NYAL | | 27 | ±1.30 | ±2.34 | ±2.32 | | ±0.22 | ±0.31 | ±0.32 | ±0.09 | ±0.11 | ±0.10 |
| NOTO | 2280 | 19 | –4.10 | 3.61 | 2.26 | 226 | –3.52 | 1.11 | 0.81 | –0.09 | 0.26 | 0.10 |
| ONSA | | 24 | ±0.91 | ±1.85 | ±1.73 | | ±0.11 | ±0.20 | ±0.18 | ±0.10 | ±0.12 | ±0.11 |
| NOTO | 1371 | 21 | –3.39 | 2.51 | 1.66 | 226 | –2.98 | 1.81 | 0.92 | –0.21 | 0.21 | 0.12 |
| WETT | | 22 | ±0.61 | ±1.14 | ±1.20 | | ±0.11 | ±0.22 | ±0.19 | ±0.05 | ±0.06 | ±0.06 |
| NYAL | 2387 | 31 | +2.17 | 4.03 | 1.56 | 206 | +1.44 | 1.28 | 0.50 | +0.22 | 0.63 | 0.25 |
| ONSA | | 31 | ±0.86 | ±1.47 | ±1.52 | | ±0.15 | ±0.25 | ±0.22 | ±0.06 | ±0.12 | ±0.12 |
| NYAL | 3283 | 162 | +1.67 | 2.49 | 2.06 | 206 | +1.03 | 1.41 | 0.24 | +0.24 | 0.42 | 0.10 |
| WETT | | 174 | ±0.25 | ±0.49 | ±0.52 | | ±0.14 | ±0.22 | ±0.21 | ±0.06 | ±0.12 | ±0.12 |
| ONSA | 919 | 36 | –0.75 | 3.42 | 1.15 | 243 | –0.23 | 0.57 | 0.46 | +0.19 | 0.13 | 0.14 |
| WETT | | 37 | ±0.49 | ±0.93 | ±0.96 | | ±0.08 | ±0.13 | ±0.13 | ±0.04 | ±0.07 | ±0.07 |

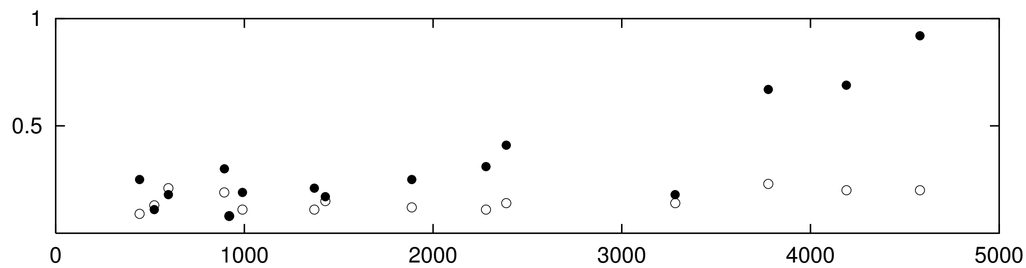


Figure 4: Dependence of error in rate (mm) on baseline length (km) for VLBI (filled circles) and GPS (light circles) data.

# 4 Acknowledgement

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